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Puzzling Movements in U.S. Iron-Ore Productivity

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ABSTRACT

The early 1980's was a time of crisis in the U.S. iron-ore industry as foreign competition threatened the industry's survival. In response to this crisis, the U.S. iron-ore industry doubled its labor productivity in a few years — an historically unprecedented feat. In this paper I show that this doubling was due to selection and to increases in the efficiency of labor. The latter factor accounted for the vast majority of the increase. Changes in work rules seems to have accounted for the majority of the increase in the efficiency of labor.

1. Introduction

The early 1980's was a time of crisis in the U.S. iron-ore industry. Production of U.S. integrated steel plants, the primary users of U.S. iron-ore, fell in half between 1979 and 1982. The fall was in good part due to increases in foreign steel competition. But not only was the U.S. integrated steel industry shrinking rapidly, it was considering increasing its use of foreign iron-ore. Brazil, a major iron-ore comptetitor, had recently expanded its capacity and lowered its costs of production.

In response to this crisis, the U.S. iron-ore industry doubled its labor productivity in a few years — an historically unprecedented feat. For example, labor productivity, measured in long tons of iron-ore produced per hour, had changed little from the middle 1960's until the early 1980's. From the early 1980's to the late 1980's, labor productivity doubled. Minnesota iron-ore producers, who produce the majority of U.S. iron-ore and are a focus of this study, experienced a similar productivity increase. At the end of the 1980's, Minnesota production aproached its pre-crisis levels but it was produced with half the hours.

In this paper, I argue that this productivity record of the U.S. iron-ore industry is a puzzle for standard economic theory.

I focus on the path of labor productivity in the middle 1980's. I begin by listing the factors that may have accounted for the doubling of labor productivity over this period. The factors that I consider include: selection (low productivity mines may have closed or shrunk relative to high productivity mines); new technological developments; substitution of other inputs, like capital, for labor; changes in scale of mines; and changes in the efficiency units of labor that are provided per hour of work (the quality of the workforce may have improved or work rules may have changed).

Selection accounts for some, but only a small portion, about a fourth, of the increase in labor productivity. Of the eight mines that were operating at the beginning of the 1980's, two were closed in the middle 1980's. A small, above-average productivity mine closed permanently. An average-sized, low-productivity mine was also closed (though it reopened in 1990 at much higher productivity levels). Productivity increased significantly in the middle 1980's at all of the other six mines.

What accounted for the productivity increases at the six continuing mines? No new technological developments were introduced over this period. Other inputs, like capital, were not substituted for labor. And changes in scale were not a factor in productivity movements. As I show below, I find that a single factor, increases in the efficiency units of labor per hour worked, accounted for essentially the entire increase in productivity at these mines. Hence, this factor accounted for about three fourths of the overall increase.

What were the sources of increases in the efficiency of labor? Industry observers during this period universally pointed to changes in workules as a major source of productivity gain. Although trying to divvy up the increase in the efficiency of labor between workrule changes and other sources (like an increasing quality of the workforce) seems difficult, I have evidence that suggests workrule changes were very important. The first type of evidence is that many narrow job classifications were eliminated after the crisis. The second type of evidence is more quantitative. I have data that divides the hours worked at mines into that worked at various locations (e.g., at the mine, in plants and in the shops (where machinists were located)). The increase in efficiency units of labor per hour worked after the crisis varied dramatically across locations. Those locations that had the most the stringent workrules, like the shops, had the biggest increases in efficeincy units per hour worked.

That a large portion of the productivity increases were achieved by changes in workrules is a puzzle for standard economic theory. Why didn't producers institute these changes earlier?[1]

Let me now turn to discuss the industry and how it achieved its productivity gains. At the end of the paper I discuss the lessons this episode provides.

2. The Iron-Ore Industry

In this section I briefly discuss some broad details of the iron-ore mining and production process. I then describe the "shocks" that hit the United States industry in the early 1980's.

Iron-ore is mined, of course, in order to produce steel. It is smelted in blast furnaces (along with coke and limestone) to produce pig iron, which is then processed into steel. Throughout history, up until the late 1950's, iron-ore mining involved extracting material from the earth that was relatively high in iron content. Such iron-ore is often referred to as natural or high-grade iron-ore and typically contains on the order of 60 to 70 percent iron. This iron-ore does not require major processing before it can be smelted.

High-grade iron-ore deposits in the United States were quickly depleted over the first half of the 20th century. The U.S. iron-ore industry was headed for extinction. One possibility for the industry's survival lay in taconite, another type of iron-ore. The problem with taconite was that in order to be used in blast furnances, it would have to undergo major processing. Taconite is a hard rock, whereas natural iron-ore is a soft material. Moreover, taconite contains only a small percentage of iron, averaging from 15 to 30 percent iron. Despite these

[1]Note that by "producer," I refer collectively to all parties that have claims on, or stakes to, the future returns in this industry, such as the managers of the mines, the owners of the mines, the unionized workforce at the mines and even the state legislators where the mines are located. It is the interaction among all these groups that lead to the decisions made, and productivity achieved, in this industry.

severe disadvantages, an economical technique to process taconite into taconite pellets was developed at the University of Minnesota during the 1940's and 50's.[2]

The first commercial mining and production of taconite pellets occurred in the late 1950's in Minnesota. Taconite production soon spread to other U. S. locations and later to other parts of the world. Taconite pellets have grown in their share of U. S. production. By the middle 1980's, taconite pellets accounted for the vast majority of U.S. iron-ore production. Today, taconite pellets account for virtually all the iron-ore produced in the United States, though natural iron-ore still accounts for the majority of world production.

The steel industry, and hence the iron-ore industry, has always been a highly cyclical industry. But the shocks that hit the United States iron-ore industry in the early 1980's were a different matter. The future of the industry was again called into question (this time because of foreign iron-ore competition and not a depletion of domestic iron-ore). Let me briefly discuss some of the reasons why the U.S. iron-ore industry faced much greater competition from foreign iron-ore producers.

First, there was a shifting of the geographic location of integrated steel production away from the United States and primarily towards Asia. This process had been happening for years, however, it accelerated in early 80's. Part of this acceleration was due to the surge in automobile imports in the late 1970's and early 1980's. These imports were produced in foreign countries with foreign steel. Later in the 1980's, many foreign car companies built cars in the United States but many of the parts, like engines, continued to be imported. That the geographic shift in production of steel put U.S. iron-ore producers at a competitive disadvantage is due to the fact that iron-ore has a very high ratio of shipping cost to product

[2]See E.W. Davis, *Pioneering With Taconite.*

value. It is costly to transport.

The pressure on U.S. integrated steel producers can be seen in the time path of their production. In Figure 1, I plot production by U.S. integrated steel producers over the period 1965-95. From 1979 to 1980, production of U.S. integrated steel plants fell 20 percent; from 1979 to 1982, it fell 50 percent; by 1994, U.S. integrated steel production had only climbed back to 60 percent of its 1979 level.

Second, even if there had been no geographic shift in steel production, Brazil dramatically increased their iron-ore production capacity and also reduced the costs of making iron-ore. Even as U.S. producers doubled their productivty between 1981 and 1987, imports from Brazil doubled between these two years.

3. Industry Productivity Record

In this section, I discuss the U.S. iron-ore productivity record.

In Figure 2, I plot the U.S. production of iron-ore per man hour for the period 1965-1990. Output is measured in metrics tons, a physical quantity. This data is from the Bureau of the Mines. In 1965, 1.90 metric tons of iron-ore were produced per manhour. Labor productivity did not change much throughout the late 60's and 1970's. In 1982, 2.09 metric tons of iron-ore were produced per manhour. Five years later, in 1987, labor productivity had nearly doubled: 4.08 metric tons of iron-ore were produced per manhour. Labor productivity has decreased somewhat since this peak in 1987 but was still 3.59 in 1990.

The production in Figure 2 includes both natural iron-ore and taconite pellets. Producing taconite pellets requires a greater labor input than producing natural iron-ore (for a given amount of iron-ore of a given iron content). Given the different labor requirements for each type of iron-ore, it is important to examine the productivity record of each iron-ore separately.

The Census of Mineral Industries provides some data that distinguishes natural and taconite iron-ores. While I use some of this data below, it has significant limitations. It is subject to disclosure restrictions, so only industry aggregates are published. Hence, data are not available on a mine-by-mine basis. It is also only available at five year intervals.

Annual data on a mine-by-mine basis can be obtained from individual states and counties. For example, the State of Minnesota collects data on the production of taconite through time and by mine (for tax purposes). Within Minnesota, counties collect hours devoted to taconite production data through time and by mine (for mine safety purposes). I focus on this data below. The drawback of this data relative to the Census of Minerals is that there are much fewer variables available. The data is primarily output and hours worked by mine and by type of iron-ore.

In the remainder of the paper I focus on taconite production in Minnesota which accounts for about three quarters of the industry over the period. In Figure 3, I plot the production of Minnesota taconite per man hour for the period 1965-1995. Output is measured in long tons, a physical quantity. The productivity pattern is similar to that in the United States overall, though there were some productivity gains through the late 60's and 70's. In 1965, 1.40 long tons of iron-ore were produced per manhour. In 1981, 1.88 long tons of iron-ore were produced per manhour. Five years after 1982, the productivity low, in 1987, labor productivity had doubled: 3.79 tons of iron-ore were produced per manhour. Labor productivity has decreased somewhat since this peak in 1987 but was still 3.45 in 1990.

4. How Productivity Gains Were Achieved

How were these industry productivity gains achieved in Minnesota? In this section, I examine those factors that may have accounted for this doubling of labor productivity in this five year period in the middle 1980's. The factors that I consider are: selection; new technological developments; substitution of otehr inputs for labor; and changes in the efficiency units of labor that are provided per hour of work. My goal is to make a quantitative assessment of each of these factors.

My strategy is to compare industry productivity between the years 1981 and 1987. I choose 1981 because this year represents a productivity peak before the crisis. I focus on 1987 because the output in 1987 of the mines that do not close because of the crisis has essentially recovered to their 1981 output levels. By comparing years when output is similar, I can control for lots of factors. Of course, the concern is that the two years are not so far aprat that other factors change.

My strategy is as follows. Let R denote the ratio of industry productivity between two dates. I ask what the ratio of productivities would be if selection were the only change. Let $\widehat{R}$ be the ratio. I then add another factor, say substitution of other inputs for labor, and calculate $\widehat{R}$ with the two factors. And so on. For 1981 and 1987, $R = 2.011$.

A. Selection

Perhaps the most obvious reason for the increase in industry productivity is selection. Following an increase in competition, perhaps the least productive plants were forced to close, leaving only the most productive. Moreover, among plants that continued to operate, perhaps the msot productive gained share. In order to formally consider this factor, I decompose the increase in labor productivity into various factors.

Before presenting such a decomposition, it is clear from looking at the mine productivity data in Figure 4 that selection is likely not a big factor in the increase in industry labor productivity. In Figure 4, for each of the eight mines engaged in the production of taconite pellets in the early 1980's, I plot mine labor productivity over time. Six of the mines had been in operation from at least the middle 1960's — Butler, Erie/LTV, Eveleth, Reserve/Northshore, National, and Minntac. Two had begun operations in the industry expansion at the end of the 1970's — Hibbing and Minorca. The industry productivity pattern is observed at each mine, though the increase in productivity differs across mines. Two mines were closed during the middle 1980's; Butler closed permanently, even following significant produtivity gains, and Reserve closed temporarily, reopening at higher productivity levels.

In order to formally decompose labor productivity, let y_{it} and n_{it} denote output (long tons of taconite pellets) and hours at mine i at date t, respectively. Let $Y_t = \sum_{i \in M} y_{it}$ and $N_t = \sum_{i \in M} n_{it}$ denote industry output and hours. The sources for each of these variables is given below. Let industry labor productivity at date t be denoted Z_t and mine labor productivity by z_{it}. Then Z_t can be expressed as a weighted average of the z_{it} as

$$Z_t = \frac{Y_t}{N_t} = \frac{\sum_{i \in M} y_{it}}{\sum_{i \in M} n_{it}} = \sum_{i \in M} \left(\frac{n_{it}}{\sum_{j \in M} n_{jt}} \right) \frac{y_{it}}{n_{it}} = \sum_{i \in M_t} s_{it} z_{it}$$

where M_t denotes the set of mines in operation at date t and s_{it} the share of mine $i's$ hours in total hours.

Consider the following decomposition of the change in industry labor productivity between date t and t', where "Δ" is the difference operator (for example, $\Delta Z_{t,t'} = Z_{t'} - Z_t$):

$$\begin{aligned} (1) \qquad \Delta Z_{t,t'} &= \sum_{i \in C_{t,t'}} s_{i,t} \Delta z_{it,t'} + \sum_{i \in C_{t,t'}} (z_{it} - Z_t) \Delta s_{it,t'} + \sum_{i \in C_{t,t'}} \Delta z_{it,t'} \Delta s_{it,t'} \\ &+ \sum_{i \in E_{t,t'}} s_{i,t'} (z_{it'} - Z_t) - \sum_{i \in X_{t,t'}} s_{i,t} (z_{it} - Z_t) \end{aligned}$$

where $C_{t,t'}$ is the set of mines that operated in t and t' (continuing mines), $E_{t,t'}$ is the set of mines that operated in t' and not t (entering mines), and $X_{t,t'}$ is the set of mines that operated in t and not t' (exiting mines). There are five terms in the decomposition. Let $term_j$ refer to the jth term (where I let $term_5 = -\sum_{i \in X_{t,t'}} s_{i,t}(z_{it} - Z_t)$). The first term is the increase in industry productivity due to the continuing mines increasing their productivity (often called the within mine term). The second term is the increase in productivity resulting from the above-average continuing mines expanding their industry share relative to the below-average productivity mines (often called the between mine term). The third term is the cross-mine term. The fourth term is the increase in productivity due to entrants (which is zero in this case since the set of entrants is empty). The fifth term is the increase in productivity due to exits.

Table 1 gives some information on the decomposition for $t = 1981$ and $t' = 1987$. It presents $\frac{\Delta Z}{Z} \times 100$ and $\frac{term_j}{Z} \times 100$, $j = 1, 2, 3, 5$. The second column shows that from1981 to 1987, labor productivity increased by $\frac{\Delta Z}{Z} \times 100$ =101%. This increase equals the sum of $\frac{term_1}{Z} \times 100 = 72.8\%$, $\frac{term_2}{Z} \times 100 = 8.1\%$, $\frac{term_3}{Z} \times 100 = 14.8\%$, and $\frac{term_5}{Z} \times 100 = 5.5\%$. The increase in productivity at continuing mines hence accounts for 72.8÷101.1=72.0% of the industry productivity increase.

We can express the ratio of industry productivities at the two dates, R, as

$$R = \frac{Z_{t'}}{Z_t} = 1 + \frac{\Delta Z_{t,t'}}{Z_t} = 1 + \frac{\sum_j term_j}{Z_t}$$

I take

$$\widehat{R} = 1 + \frac{\sum_{j \neq 1} term_j}{Z_t}$$

to be the source of productivity gain between two years that results from selection. In this case, $\widehat{R} = 1 + \frac{\sum_{j \neq 1} term_j}{Z_t} = 1.2820$, where again, $R = 2.011$.

In the remainder of the paper, I want to focus on the productivity gains in the continuing mines. I ask what was the gain in productivity from a factor, like substitution of capital for labor, and label the gain $\Delta\widehat{z}_{it,t'}$. I then form an estimate for $term1$ based on the gain from this factor, labeled $\widehat{term}1 = \sum_{i \in C_{t,t'}} s_{i,t} \Delta\widehat{z}_{it,t'}$. Then $\widehat{R}$ becomes

$$\widehat{R} = 1 + \frac{\widehat{term}_1}{Z_t} + \frac{\sum_{j \neq 1} term_j}{Z_t}$$

from selection and this factor. I then add other factors.

B. New Technology

While the middle 1980's was a period of new technology adoption in steel, as continuous casting was adopted in the United States, there was no significant changes in the way taconite was produced. So, the gain in productivity at the existing mines was not because of technology adoption or changes in production methods.

C. Changes in Scale, Non-Labor Inputs, and Efficiency of Labor Per Hour

Let me introduce some notation. Let e_t denote energy input, m_t materials input, k_t capital input and l_t the efficiency units of labor, where $l_t = \gamma_t n_t$ and where the multiple

γ_t, the efficiency units of labor per hour of work, may depend on things like quality of the workforce (e.g., education experience, etc.), workrules and so on. If I had the technology at a mine, say $f(\cdot)$, and a list of mine inputs at two dates, then my estimate of the difference in mine productivity between the two dates, $\Delta\widehat{z}_{t,t'}$, would be

$$\Delta\widehat{z}_{t,t'} = \frac{f(e_{t'}, m_{t'}, k_{t'}, l_{t'})}{n_{t'}} - \frac{f(e_t, m_t, k_t, l_t)}{n_t}.$$

I could then try to decompose productivity gains among factors, like change in capital, scale of operation, labor efficiency, etc.

But I do not have such detailed mine input data. But I am able to conclude with some confidence that the increase in productivity at mines was primarily due to increases in the efficiency of labor per hour worked. Let me present an outline of the argument and then give details below. First, I compare years when output is roughly the same. Second, I argue that the capital stock at each mine is not much different between the years. Third, there is not much possibility of substitution bewteen electricity and labor or between materials and labor. Hence, electricity usage and materials usage are roughly the same between the years as well. This means the efficiency units of labor are roughly the same. Hence, since hours fall alot, the efficiency units per hour must have gone up alot. Roughly then, the increase in productivity is proportional to the increase in the efficiency units of labor per hour, that is,

$$\Delta\widehat{z}_{t,t'} = (\gamma_{t'} - \gamma_t)\frac{f(\cdot)}{l}$$

A key question then is what increased efficiency units of labor. But let me get to that later. Let me now make these arguments.

Changes in Scale

As I mentioned, 1987 output in the mines that continued operation was back to its 1981 levels. This can be seen in Figure 5.[3]

Substitution of Other Inputs for Labor

Let me briefly describe the production process for taconite pellets. At the *mine* pit itself, holes are drilled into the taconite and loaded with explosive. After the taconite is broken up with explosions, steam shovels load it into huge trucks and or trains for delivery to the *plants.* The first processing task at the plants is to crush the taconite. There are a whole series of crushers. During crushing, iron is separated from the rest of the rock with magnets. Then it must be agglomerated and cooked into pellets. Keeping the equipment at the mine and plants running smoothly obviously requires large effort. This is the task of the last major location, the *shops.* The machinists and like workers are at the shops.

What are the inputs in these mines? The major inputs are listed in Table 2, taken from a report that provides little explanation of how the cost figures were arrived at. I put in costs since they give likely provide at least ballpark information.

Now, was capital substituted for labor? The evidence I have at this point suggests it was not. One piece of supporting evidence comes from the aggregate capital stock data provided by the Census of Mineral Industries. That is given in Table 3. The industry capital stock did not go up between 1982 and 1987. There are many qualifications I need to mention: what was happening to capital good prices?; also, some mines closed, so the capital at the remaining mines went up a bit (but the mines that closed were small, low capital mines). I

[3] As a sidenote, figure 6 shows that from the historical record, a decrease in hours at the mine level typically led to a decrease in mine productivity, not an increase.

hopefully will get better information on mine capital in the future.

Now, what about other substitution possibilities? I think the actual production process at these mines suggests that there is little substitution possibilities between electricity and labor or materials and labor. Some evidence of this is given in Table 3. In Table 3, the electricity usage per long ton produced changes very little between 1982 and 1987 though the level of output changes alot. Ammonium nitrate usage, an explosive, is also nearly proportional to output. Some other inputs are not so clearly proportional to output, and how much of this is due to compositional effects, and how much to some other factors, I do not know at this point.

I conclude then, that as a working hypothesis, that the efficiency units of labor did not change much between 1981 and 1987 at the six Minnesota plants. But the hours worked at these mines did change. In all mines, hours fell, though the drop differed alot across mines. The hours worked in these mines can be seen in Figure 6.

Since hours fell, and efficiency units of labor did not change much, the efficiency of labor per hour worked increased significantly. I now turn to those increases.

Changes in Efficiency Units of Labor

The productivity increases at existing mines were due primarily to increases in the efficiency of labor. I next try to divvy up these increases in labor efficiency among its potential sources. One obvious source is an increase in worker quality as the workforce shrinks. Another source is a change in workrules. This latter factor is often cited by industry analysts as a major source of productivity gain. Let me discuss these and other potential sources.

Let me start with changes in workrules since these are thought by industry observers to have been very important and since I have some ways of trying to indentify their importance.

Workrules and job classifications varied by location of work, across mine, plant and shops. The greatest number of job classifications were for the workers in the shops. Before the crisis, there were many different types of classifications. After the crisis, many jobs at the shops were rolled into one. For example, whereas before there were separate classifications for plumber, pipefitter, machinist, and welder, after the crisis these were all roled into the job of millwright. Such narrowing of job classifications is some evidence that easy workrules was important for productivity gains.

There is other evidence as well. MINNTAC, the biggest mine and that owned by US Steel, reported hours worked to the county mine inspector by location, that is, at the mine, at the plants and at the shops. If changes in workrules were important, then we should expect to see a much larger increase in the efficiency units of labor per hour worked at the shops. I present this data in Table 4, where output is in long tons. If we compare 1978 and 1989, two years with similar output, one before the crisis and one after, we see that hours worked at the mine fall by about a factor 2, hours worked at the plant fall by about a factor 2, and hours worked at the shops fall by about a factor of 4. Amazing.

How to use this data to try to get at workrule importance? Lets change the production function to

$$f(e_t, m_t, k_t, l_{mt}, l_{pt}, l_{st})$$

where $l_{jt} = \gamma_{jt} n_{jt}$, $j = m, p, s$. Now, lets use a model for efficiency units that attributes them to two sources, workrules and all else. That is, lets use

$$l_{jt} = \gamma_{jt} n_{jt} = \omega_{jt} \sigma_t n_{jt} \tag{2}$$

where ω_j represents workrules (it is bigger the less stringent are workrules) and where σ represents all else (it is bigger with more education, etc.).

If we assume no substitution between the hours worked at each location, then $l_{jt} = l_{jt'}$. Using (2) above, and $l_{jt} = l_{jt'}$, we have

$$\frac{n_{jt}}{n_{jt'}} = \frac{\omega_{jt'}}{\omega_{jt}} \cdot \frac{\sigma_{t'}}{\sigma_t}$$

Using MINNTAC, we have

$$\frac{\omega_{mt'}}{\omega_{mt}} \cdot \frac{\sigma_{t'}}{\sigma_t} = 2 \text{ and } \frac{\omega_{pt'}}{\omega_{pt}} \cdot \frac{\sigma_{t'}}{\sigma_t} = 2 \text{ and } \frac{\omega_{st'}}{\omega_{st}} \cdot \frac{\sigma_{t'}}{\sigma_t} = 4$$

where all the ratios are assumed greater than one. Suppose we take the worst case scenario for work rules, that is, $\frac{\sigma_{t'}}{\sigma_t} = 2$. Then $\frac{\omega_{st'}}{\omega_{st}} = 2$. How much of a productivity increase comes from this change alone? Since shop hours before the crisis were at least half of total hours, productivity at a mine after the crisis because of this factor alone woul be 1.33 times greater than its pre-crisis level. This effect hits only continuing mines of course. But this effect is as large as the selection effect. And this seems to be a lower bound for workrules.

Another reason I think workrules are a compelling factor is because some of the other explanations are not convincing. Improvements in worker quality is certainly a candidate for contributing some of the increase to labor efficiency. Perhaps the workforce that remained was more experienced, more educated and generally the highest motivated workers. At this point, I have not come up with any objective measures of worker quality. But let me say that I am skeptical that this factor is of large importance. Why? Because the way workers are to leave employment is determined by union contract, primarirly seniority. Even if the management and the union could identify the best workers and wanted to keep them, they are bound by contracts. A key question, then, is how quality is correlated with seniority.

References

[1] Baily,

[2] Baily,

[3] Borenstein

[4] Clark, Gregory

[5] Foster, Haltiwanger

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[8] Parente and Prescott, "Monopoly Rights:

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Table 1					
Labor Productivity Growth: A Decomposition					
Years	Percentage Growth	Percentage Growth Equals the Sum Of:			
		Within Mine Term	Between Mine Term	Cross Mine Term	Exit Term
1981/1987	101.1%	72.8%	8.1%	14.8%	5.5%

Table 2			
Costs of Production and Transportation Long Ton of Taconite Pellet "Model" Mine in Minnesota, 1986			
	Units Per Long Ton of Pellets	$ Per Long Ton of Pellets	Totals
Energy:			
Electricity	110 kWh	4.50	
Natural Gas	400 cu. ft.	1.60	
Diesel or Fuel Oil	1 gal	0.90	
Gasoline	0.1 gal	0.10	
Energy Total			7.10
Materials:			
Grinding Steel	5 lb	1.10	
Explosives	3 lb	0.60	
Bentonite	20 lb	0.60	
Lubricants	0.06 gal	0.25	
Tires	---	0.90	
Chemicals	---	0.20	
Repair and Maintenance Parts	---	1.75	
Materials Total			5.40
Labor (0.26 hrs. per long ton)			5.80
Taxes (Minnesota production taxes)			2.50
Royalties			1.00
Interest			2.00
Depreciation			1.50
Management Fee			0.20
FOB Mine			25.50
Transport to Chicago:			
Rail to Upper Lakes Ports			3.25
Lake to Chicago			5.00
C&F Chicago			33.75

Table 3			
Inputs to and Production of Iron-Ore			
United States			
	1982	1987	1992
Production of Iron-Ore (Millions of Long Tons)	32.5	47.0	55.9
Taconite's Share of Total	(94.5)	(97.0)	(97.8)
Inputs			
Energy			
Electricity (Millions of kWh)	4,088	6,262	7,288
Kwh per long ton	(125.8)	(133.23)	(130.4)
Natural Gas (Billions of cu. Ft.)	13.0	21.0	29.7
Cu. Ft. per long ton	(400)	(446.8)	(531.3)
Fuel Oil (Distillate) (1,000 bbl)	647.4	542.7	669.6
Gallons per long ton	(0.84)	(0.48)	(0.50)
Gasoline (Millions of Gallons)	1.6	1.0	1.1
Gallons Per long ton	(0.05)	(0.02)	(0.02)
Materials			
Explosives (except a.n.)(Mil lb)	51.2	46.9	---
Lb per long ton	(1.58)	(1.00)	
Ammonium nitrate (Mil lb)	24.9	34.5	---
Lb per long ton	(0.77)	(0.73)	
Capital Stock* (Mil $)	4,353.5	4,162.2	3,812.6
Dollars Per long ton	(133.86)	(88.95)	(68.20)
*Gross Book Value (End of Yr.)			
Source: Census of Mineral Industries			

Table 4

Year	Minntac Total Hrs	Minntac Total Y	Minntac Y/Hrs	Minntac Mine Hrs	Minntac Plant Hrs	Minntac Shop Hrs
68	3899610	4573743	1.17	624151	1320769	1954690
69	4315618	6056598	1.40	637109	1236957	2441552
70	4517363	6426609	1.42	682560	1181126	2653677
71	4771712	6439695	1.35	775609	1218323	2777780
72	5639498	8674583	1.54	1073073	1608889	2957536
73	6830014	12540908	1.84	1314106	2029903	3486005
74	7135379	12616204	1.77	1281311	2146203	3707865
75	6968649	12193687	1.75	1252238	2016510	3699901
76	7153840	12294537	1.72	1429302	2077695	3646843
77	5180756	7428136	1.43	1067360	1330892	2782504
78	8742016	12927230	1.48	2050396	2573513	4118107
79	9809928	16492186	1.68	2311159	2882749	4616020
80	8229524	14147065	1.72	2089668	2036017	4103839
81	7441056	12381951	1.66	2073951	2313857	3053248
82	2646358	3307025	1.25	938757	1045938	661663
83	3323097	7708073	2.32			
84	3122858	8712123	2.79			
85	3047596	9913832	3.25			
86	1747707	5617695	3.21	565039	740041	442627
87	1788782	7668870	4.29	749370	775694	263718
88	2987181	11848960	3.97	872391	1281010	833780
89	3265593	12224575	3.74	981483	1325854	958256
90	3403550	13494697	3.96	1023896	1413406	966248
91	3353049	13294427	3.96	977781	1415371	959897
92	3329083	13180414	3.96	957173	1433303	938607
93	3371266	14261785	4.23	990123	1449975	931168
94	3407957	14289675	4.19	999174	1465147	943636
95	3527516	13644613	3.87	1022816	1530173	974527

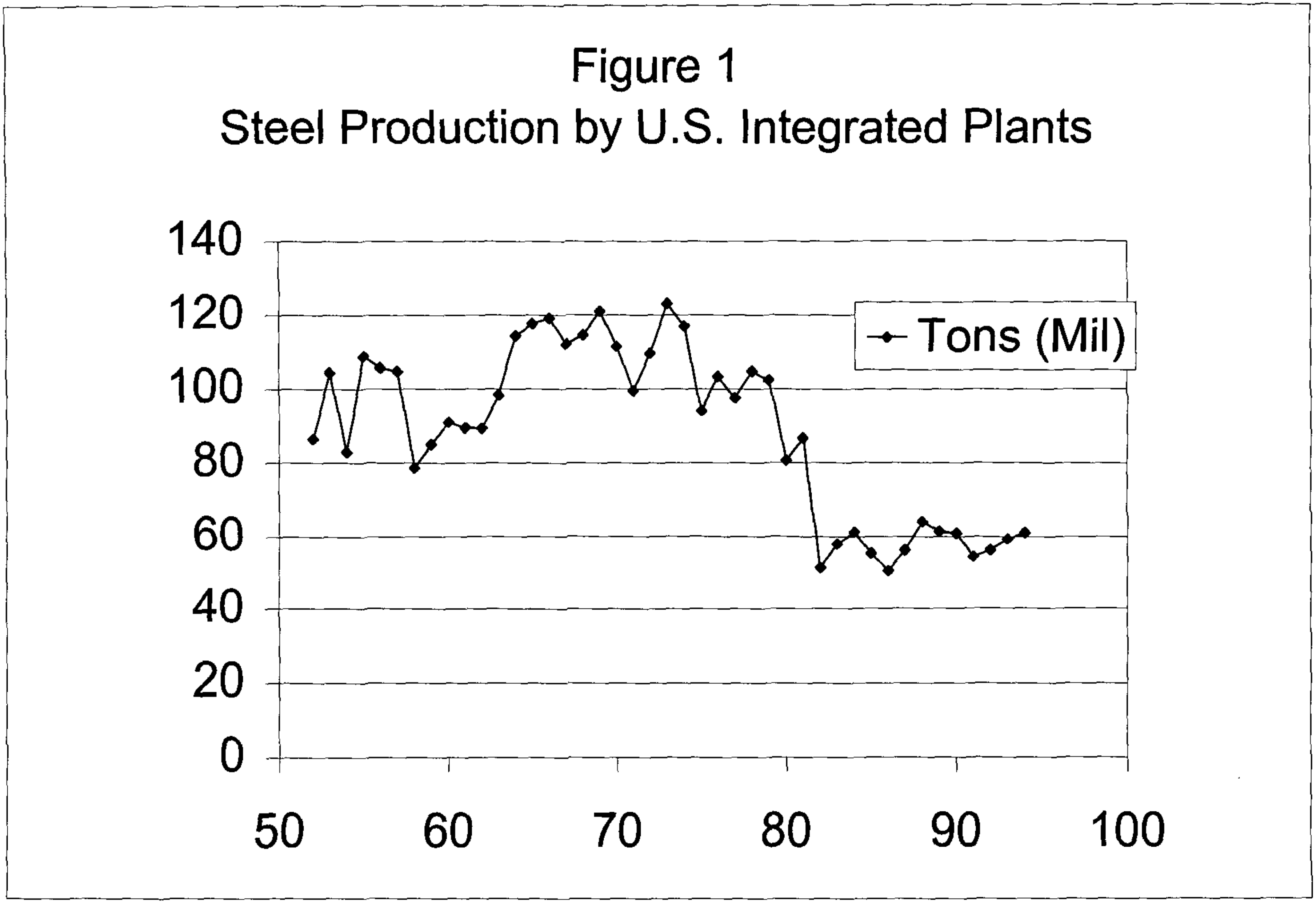

Figure 1
Steel Production by U.S. Integrated Plants
140
120
100
80
60
40
20
0
50
60
70
80
90
100
Tons (Mil)

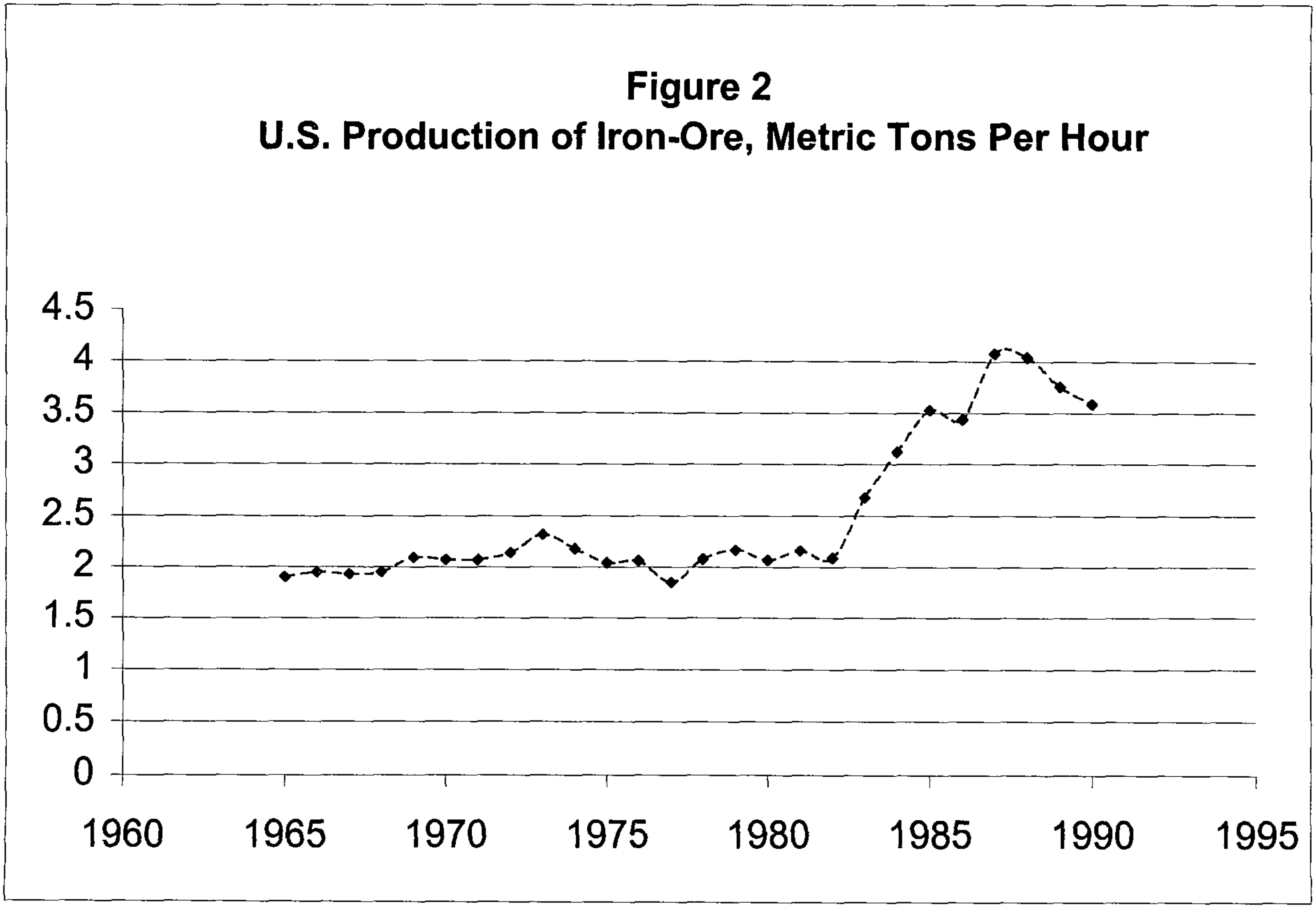
Figure 2
U.S. Production of Iron-Ore, Metric Tons Per Hour
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1960
1965
1970
1975
1980
1985
1990
1995

Figure 3

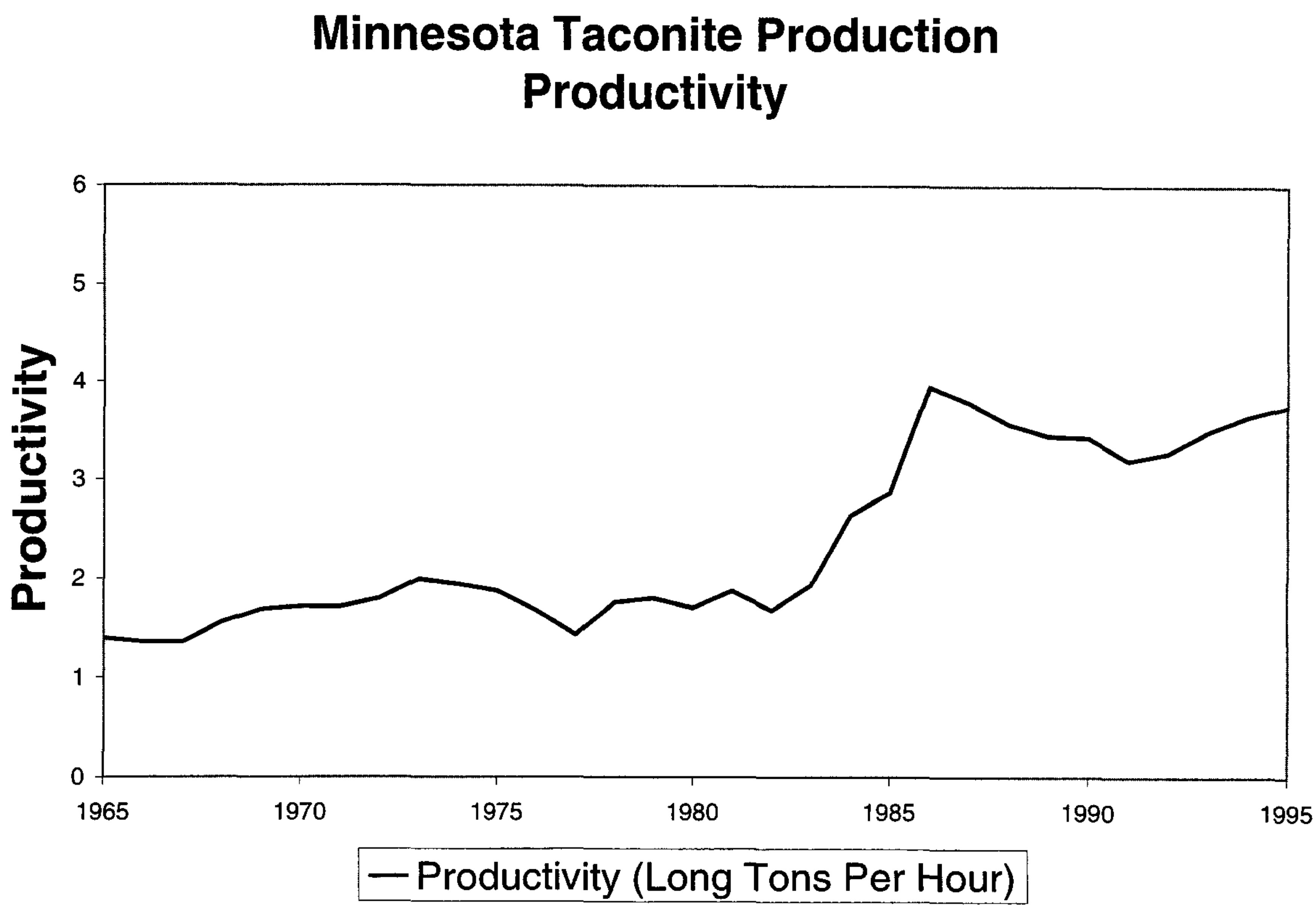
Minnesota Taconite Production
Productivity
Productivity
6
5
4
3
2
1
0
1965
1970
1975
1980
1985
1990
1995
Productivity (Long Tons Per Hour)

Figure 4 - Mine Productivity in Minnesota

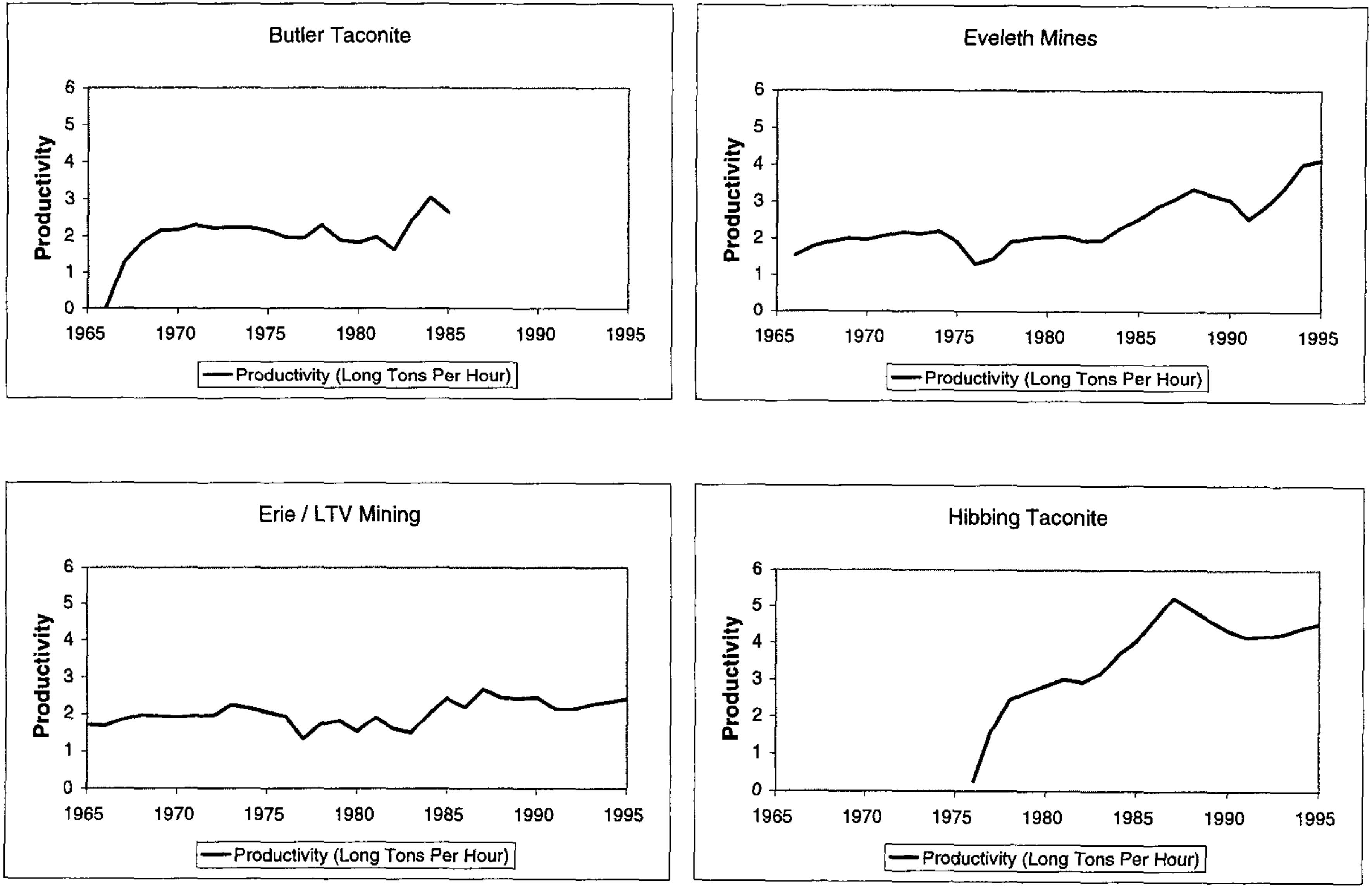

Figure 4 (continued)

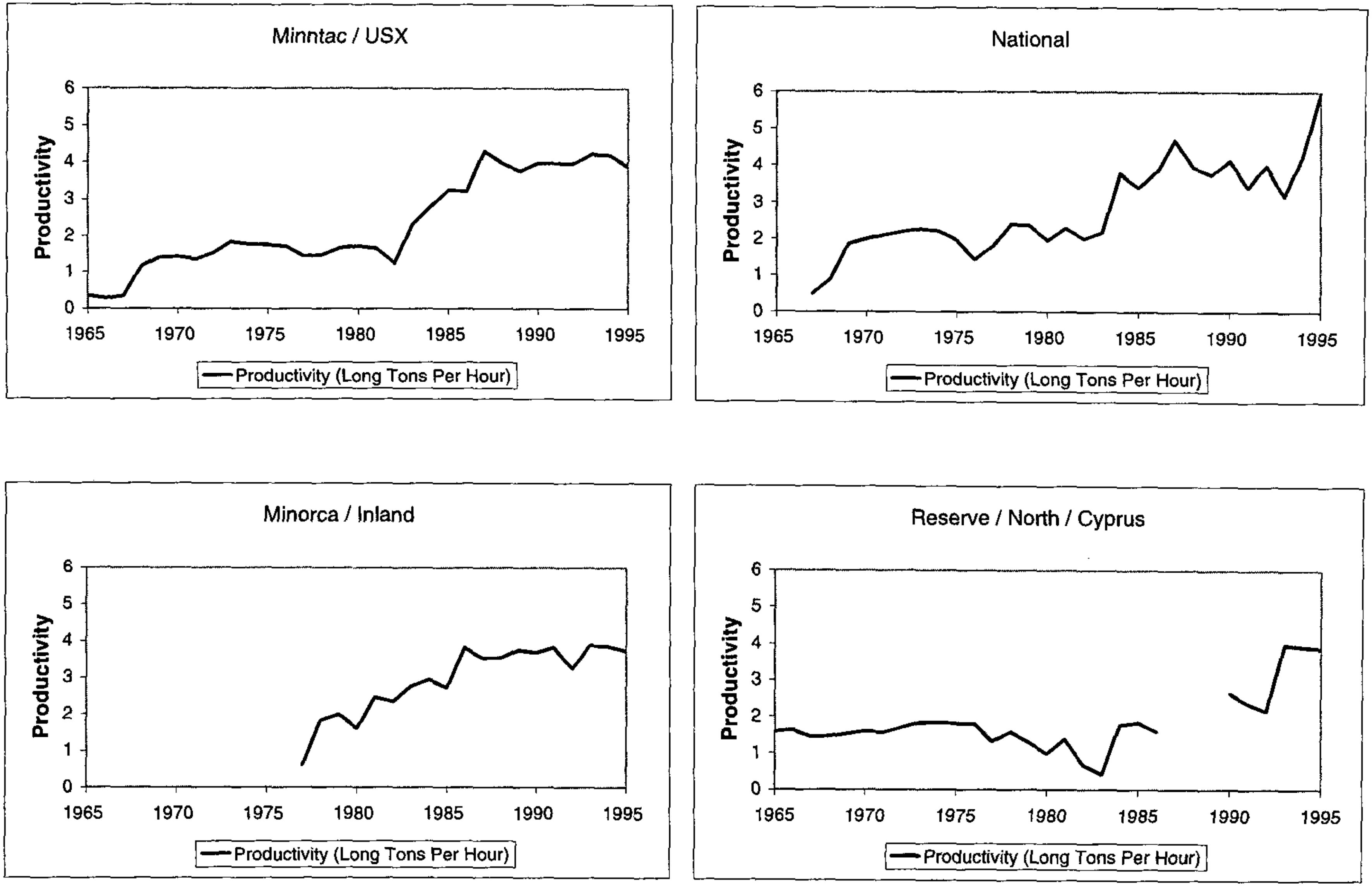

Figure 5 - Mine Output in Minnesota

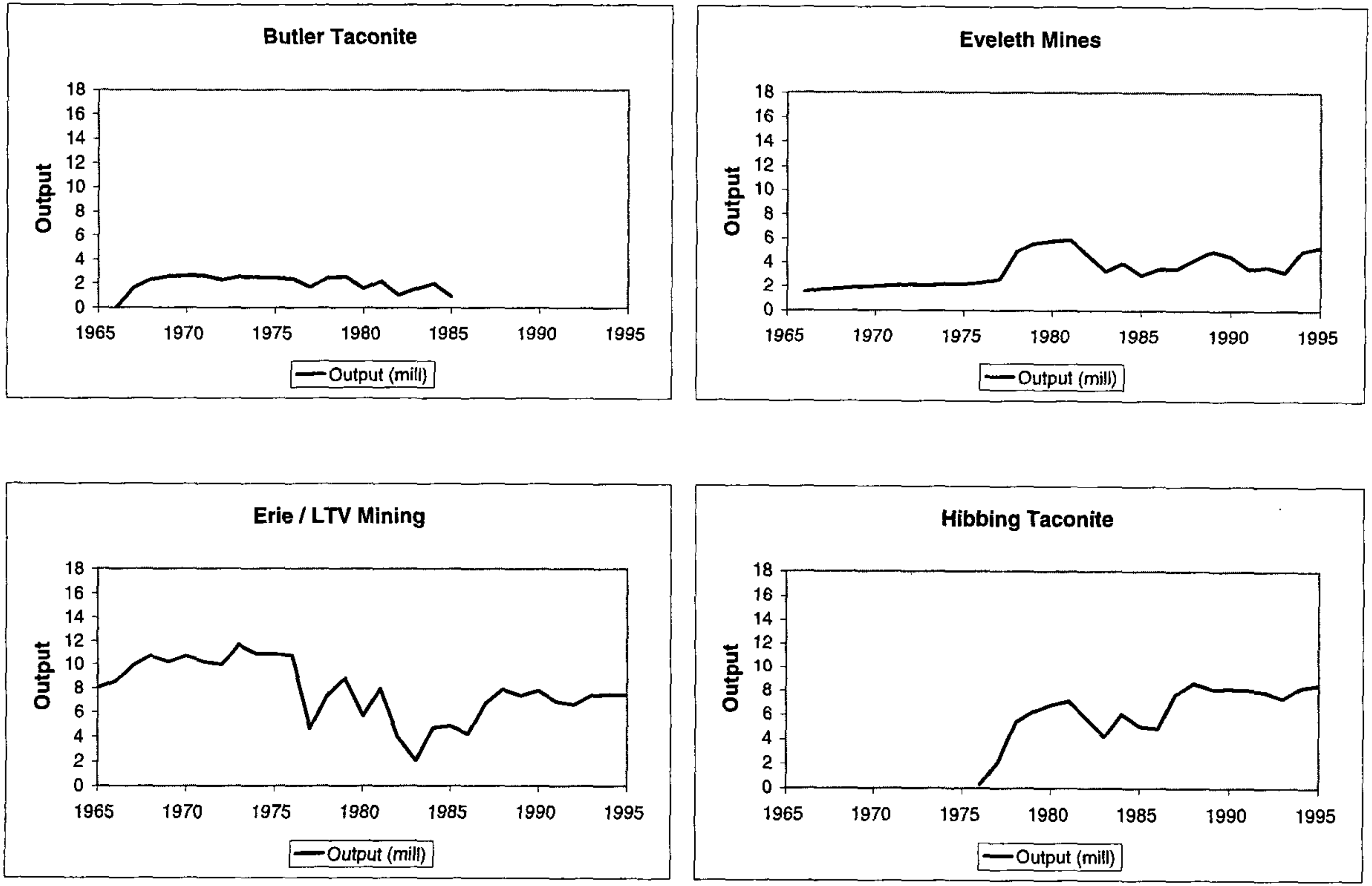

Figure 5 (continued)

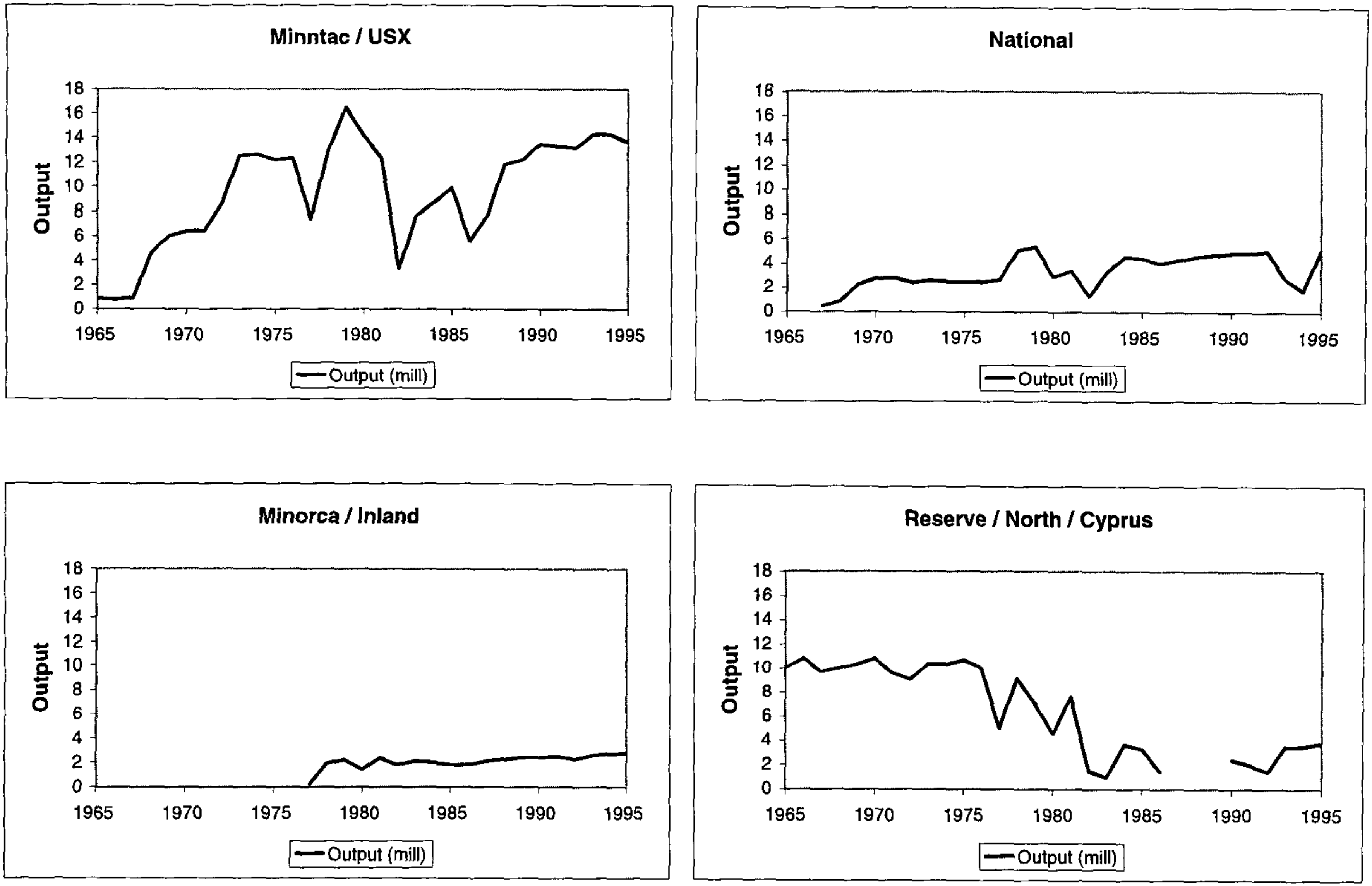

Figure 6 - Mine Hours and Productivity in Minnesota

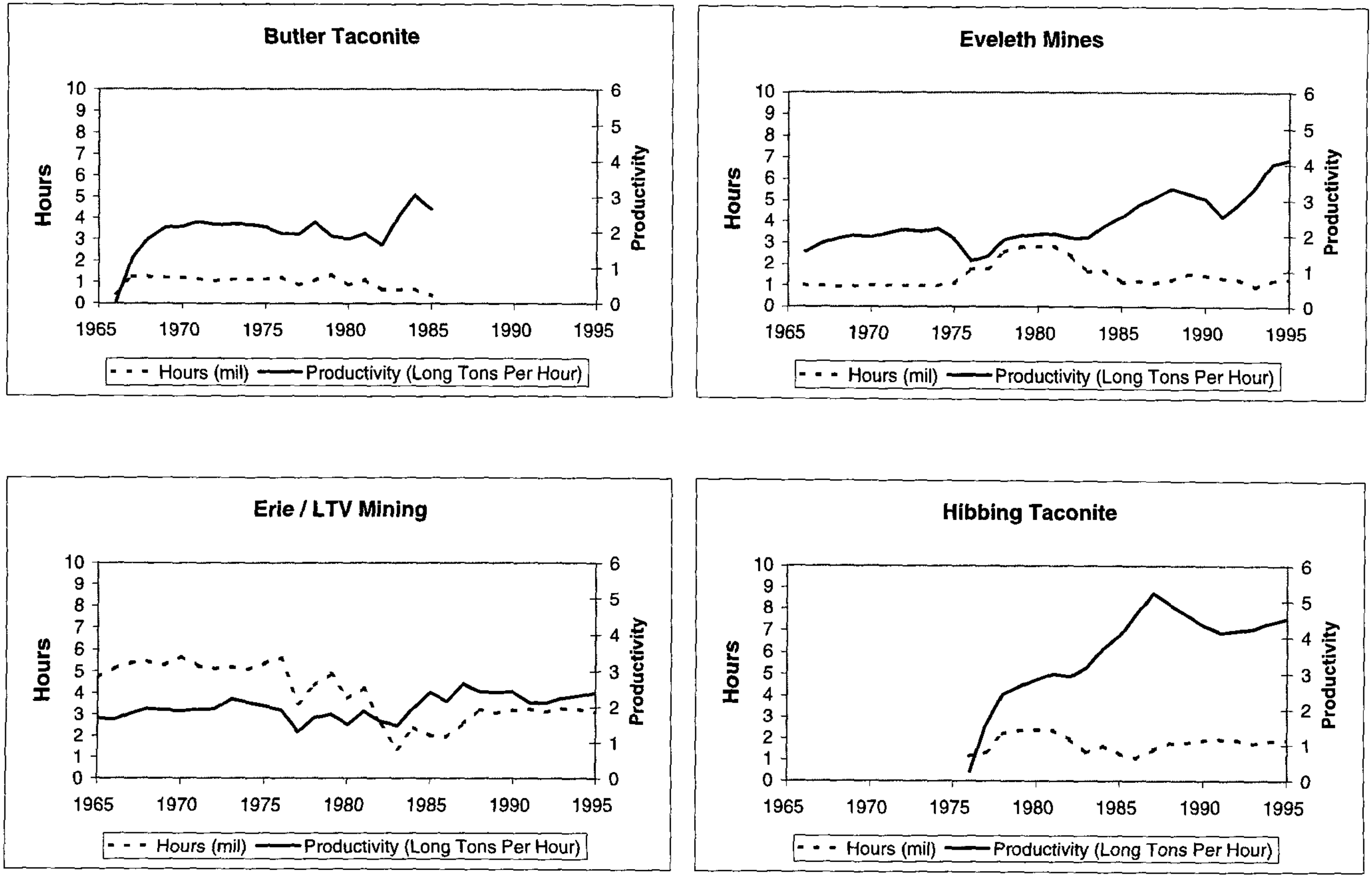

Figure 6 (continued)